

CLAIMS

- 1 1. A method for forming a transistor, the method comprising the steps of:
 - 2 a) providing a semiconductor substrate;
 - 3 b) patterning the semiconductor substrate to provide a first body edge;
 - 4 c) providing a first gate structure of a first fermi level adjacent said first body
 - 5 edge;
 - 6 d) patterning the semiconductor substrate to provide a second body edge, the
 - 7 first and second body edges of the semiconductor substrate defining a
 - 8 transistor body; and
 - 9 e) providing a second gate structure of a second fermi level adjacent said
 - 10 second body edge.

- 1 2. The method of claim 1 wherein the first gate structure of a first fermi level
- 2 comprises p-type material and wherein the second gate structure of a second
- 3 fermi level comprises n-type material.

- 1 3. The method of claim 1 wherein the first gate structure of a first fermi level
- 2 comprises n-type material and wherein the second gate structure of a second
- 3 fermi level comprises p-type material.

1 4. The method of claim 1 wherein the semiconductor substrate comprises a
2 silicon-on-insulator layer, and wherein the step of patterning the
3 semiconductor substrate to provide a first body edge comprises patterning the
4 silicon-on-insulator layer and wherein the step of patterning the semiconductor
5 substrate to provide a second body edge comprises patterning the silicon-on-
6 insulator layer.

1 5. The method of claim 1 further comprising the steps of forming a first gate
2 dielectric layer on the first body edge and forming a second gate dielectric
3 layer on the second body edge.

1 6. The method of claim 1 wherein the step of patterning the semiconductor
2 substrate to provide a first body edge comprises forming a mandrel layer on
3 the semiconductor substrate; patterning the mandrel layer to form an exposed
4 side, and forming a sidewall spacer adjacent to the exposed side, and wherein
5 a first edge of the sidewall spacer defines the first body edge.

1 7. The method of claim 6 wherein the step of patterning the semiconductor
2 substrate to provide a second body edge comprises using a second edge of the
3 sidewall spacer to define the second body edge.

1 8. The method of claim 1 further comprising the step of forming a source/drain
2 implant into the body of the transistor by performing an angled implant into
3 the transistor body.

1 9. The method of claim 1 further comprising the step of forming a substantially
2 uniform dopant concentration density in the transistor body.

1 10. The method of claim 9 wherein the step of forming a substantially uniform
2 dopant concentration density in the transistor body comprises performing a
3 plurality of angled implants into the body.

1 11. The method of claim 1 wherein the of forming a substantially uniform dopant
2 concentration density in the transistor body comprising forming a dopant
3 concentration between 0.3 N_A and 3 N_A , where N_A is defined as:

$$4 N_A = \frac{2\epsilon_{ox}Eg}{Toxs} \cdot \frac{(Toxs + \lambda)}{\left[(Toxs) + Toxw + Tsi \cdot \frac{\epsilon_{ox}}{\epsilon_{si}} \right]^2} \quad \text{Eq. 2}$$

1 12. The method of claim 9 wherein the step of forming a substantially uniform
2 dopant concentration density in the transistor body comprises performing a
3 first angled implant when the first body edge is exposed and performing a
4 second angled implant when the second body edge is exposed.

1 13. The method of claim 11 wherein the first angled implant comprises an implant
2 at approximately 45° with respect to the semiconductor substrate and wherein
3 the second angled implant comprises an implant at approximately 45° with
4 respect to the semiconductor substrate.

1 14. The method of claim 1 wherein the step of patterning the semiconductor
2 substrate to provide a first body edge comprises forming a mandrel layer on
3 the semiconductor substrate; patterning the mandrel layer, and using the
4 patterned mandrel layer to define the first body edge.

1 15. The method of claim 14 wherein the step of patterning the semiconductor
2 substrate to provide a second body edge comprises forming a sidewall spacer
3 adjacent to a gate material layer and using the sidewall spacer to define the
4 second body edge.

1 16. A method for forming a field effect transistor, the method comprising the
2 steps of:

3 a) providing a silicon-on-insulator substrate, the silicon-on-insulator substrate
4 comprising a silicon layer on a buried dielectric layer;

5 b) forming a mandrel layer on the silicon layer; patterning the mandrel layer to
6 define a mandrel layer edge;

7 c) patterning the silicon layer with the mandrel layer edge the patterning of
8 the silicon layer providing a first body edge;

9 d) forming a first gate dielectric on the first body edge;

10 e) providing a first gate structure of a first fermi level adjacent the first body
11 edge on the first gate dielectric;

12 f) patterning the mandrel layer to expose a first edge of the first gate structure;

13 g) forming a sidewall spacer adjacent the first edge of the first gate structure,
14 the sidewall spacer having a first edge and a second edge;

15 h) patterning the silicon layer with the second edge of the sidewall spacer, the
16 patterning of the silicon layer providing a second body edge, where the first and
17 second body edges of the patterned silicon layer define a transistor body;

18 i) providing a second gate dielectric on the second body edge; and

19 j) providing a second gate structure of a second fermi level adjacent the
20 second body on the second gate dielectric.

1 17. The method of claim 16 wherein the first gate structure of a first fermi level
2 comprises p-type polysilicon material and wherein the second gate structure of
3 a second fermi level comprises n-type polysilicon material.

1 18. The method of claim 16 wherein the first gate structure of a first fermi level
2 comprises n-type polysilicon material and wherein the second gate structure of
3 a second fermi level comprises p-type polysilicon material.

1 19. The method of claim 16 further comprising the step of forming a source/drain
2 implant into the body of the transistor by performing an angled implant into
3 the transistor body.

1 20. The method of claim 16 wherein the step of depositing sidewall spacer
2 material in sidewall spacer trough comprises forming a sidewall oxide layer in
3 said trough, forming a nitride layer over said sidewall oxide layer, and filling
4 said sidewall spacer trough with a deposition of oxide.

1 21. The method of claim 16 further comprising the step of forming a substantially
2 uniform dopant concentration density in the transistor body.

1 22. The method of claim 21 wherein the step of forming a substantially uniform
2 dopant concentration density in the transistor body comprises performing a
3 plurality of angled implants into the body.

1 23. The method of claim 21 wherein the step of forming a substantially uniform
2 dopant concentration density in the transistor body comprises performing a
3 first angled implant when the first body edge is exposed and performing a
4 second angled implant when the second body edge is exposed.

1 24. The method of claim 23 wherein the first angled implant comprises an implant
2 at approximately 45° with respect to the silicon-on-insulator substrate and
3 wherein the second angled implant comprises an implant at approximately 45°
4 with respect to the silicon-on-insulator substrate.

1 25. A transistor comprising:

2 a) a transistor body formed on a substrate, the transistor body having a first
3 vertical edge and a second vertical edge;

4 b) a first gate structure adjacent the transistor body first vertical edge, the first
5 gate structure having a first fermi level; and

6 c) a second gate structure adjacent the transistor body second vertical edge, the
7 second gate structure having a second fermi level.

1 26. The transistor of claim 25 wherein the first gate structure comprises p-type
2 material and wherein the second gate structure comprises n-type material.

1 27. The transistor of claim 25 wherein the first gate structure comprises n-type
2 material and wherein the second gate structure comprises p-type material.

1 28. The transistor of claim 25 wherein the transistor body comprises a portion of
2 a silicon-on-insulator layer.

1 29. The transistor of claim 25 wherein the first and second gate structures
2 comprise polysilicon.

1 30. The transistor of claim 25 further comprising a first gate dielectric between the
2 transistor body first edge and the first gate structure and a second gate
3 dielectric between the transistor body second edge and the second gate
4 structure.

1 31. The transistor of claim 25 wherein the transistor body comprises a
2 source/drain implant into the transistor body.

1 32. The transistor of claim 25 wherein the transistor body has a substantially
2 uniform dopant concentration density.

1 33. The transistor of claim 32 wherein the substantially uniform dopant
2 concentration density is comprises a plurality of angled implants into the
3 transistor selected to result in a substantially uniform dopant concentration
4 density.

1 34. The transistor of claim 32 wherein the substantially uniform dopant
2 concentration comprises a dopant concentration between 0.3 N_A and 3 N_A,
3 where N_A is defined as:

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$$N_A = \frac{2\epsilon_{ox}Eg}{Toxs} \cdot \frac{(Toxs + \lambda)}{\left[(Toxs) + Toxw + Tsi \cdot \frac{\epsilon_{ox}}{\epsilon_{si}} \right]^2} \quad \text{Eq. 2}$$

1 35. The transistor of claim 25 wherein the transistor body first edge is opposite the
2 transistor body second edge and wherein the transistor body first edge and
3 transistor body second edge are substantially perpendicular to a top surface of
4 the substrate.

1 36. A double gated field effect transistor comprising:

2 a) a transistor body, the transistor body formed from a silicon layer formed
3 above an insulator layer, the transistor body having a first vertical edge and a
4 vertical second edge, wherein the transistor body first edge and the transistor
5 body second edge are opposite each other and substantially perpendicular to
6 the insulator layer;

7 b) a first gate dielectric layer formed on the transistor body first edge;

8 c) a second gate dielectric layer formed on the transistor body second edge;

9 d) a first gate structure formed on the first gate dielectric layer adjacent to the
10 transistor body first edge, the first gate structure comprising p-type
11 polysilicon; and

12 e) a second gate structure formed on the second gate dielectric layer adjacent
13 to the transistor body second edge, the second gate structure comprising n-type
14 polysilicon.

1 37. The double gated field effect transistor of claim 36 further comprising a
2 source/drain implant in the transistor body formed by performing an angled
3 implant into the transistor body.

1 38. The double gated field effect transistor of claim 36 wherein the body
2 comprises a substantially uniform dopant concentration density.

1 39. The double gated field effect transistor of claim 38 wherein the substantially
2 uniform dopant concentration density is formed by performing a plurality of
3 angled implants into the transistor body.

1 40. The double gated field effect transistor of claim 36 further comprising a
2 polysilicon plug to electrically couple the first gate structure to the second gate
3 structure.

1 41. A method for forming a semiconductor device, the method comprising the
2 steps of:

3 a) forming a single crystal semiconductor fin having a first side and a second
4 side;
5 b) tilt implanting said first side of the single crystal semiconductor fin and tilt
6 implanting said second side of the single crystal semiconductor fin.

1 42. The method of claim 41 wherein the step of forming a single crystal
2 semiconductor fin comprises patterning a silicon on insulator layer to define a
3 transistor body.

1 43. The method of claim 41 further comprising the step of providing a first gate
2 structure of a first fermi level adjacent said first said and providing a
3 providing a second gate structure of a fermi level function adjacent said
4 second side.

1 44. The method of claim 43 wherein the first gate structure of a first fermi level
2 comprises p-type material and wherein the second gate structure of a second
3 fermi level comprises n-type material.

1 45. The method of claim 43 further comprising the steps of forming a first gate
2 dielectric layer on the first side and forming a second gate dielectric layer on
3 the second side.

1 46. The method of claim 41 wherein the step of forming the single crystal
2 semiconductor fin comprises forming a mandrel layer on a semiconductor
3 layer; patterning the mandrel layer to form an exposed side, wherein the
4 exposed side of the mandrel layer defines the first side of the single crystal
5 semiconductor fin.

1 47. The method of claim 46 wherein the step of forming the single crystal
2 semiconductor fin further comprises forming a sidewall spacer, the sidewall
3 spacer defining the second side of the single crystal semiconductor fin.

1 48. The method of claim 41 wherein the step of tilt implanting the first side and
2 tilt implanting the second side provide a substantially uniform dopant
3 concentration density in the single crystal semiconductor fin.

1 49. The method of claim 48 wherein the of forming a substantially uniform dopant
2 concentration density in the transistor body comprising forming a dopant
3 concentration between 0.3 N_A and 3 N_A, where N_A is defined as:

$$4 N_A = \frac{2\epsilon_{ox}Eg}{Toxs} \cdot \frac{(Toxs + \lambda)}{\left[(Toxs) + Toxw + Tsi \cdot \frac{\epsilon_{ox}}{\epsilon_{si}} \right]^2} \quad \text{Eq. 2}$$

1 50. The method of claim 41 wherein the step of tilt implanting said first side of
2 the single crystal semiconductor fin and tilt implanting said second side of the
3 single crystal semiconductor fin comprises implanting at approximately 45°
4 with respect to the first side and at approximately 45° with respect to the
5 second side.
